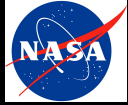




Snow and Ice Climatology of the Western United States and Alaska from MODIS

Thomas H. Painter, Chris Mattmann
Jet Propulsion Laboratory
California Institute of Technology

NCA update 20 November 2012



Further Investigators



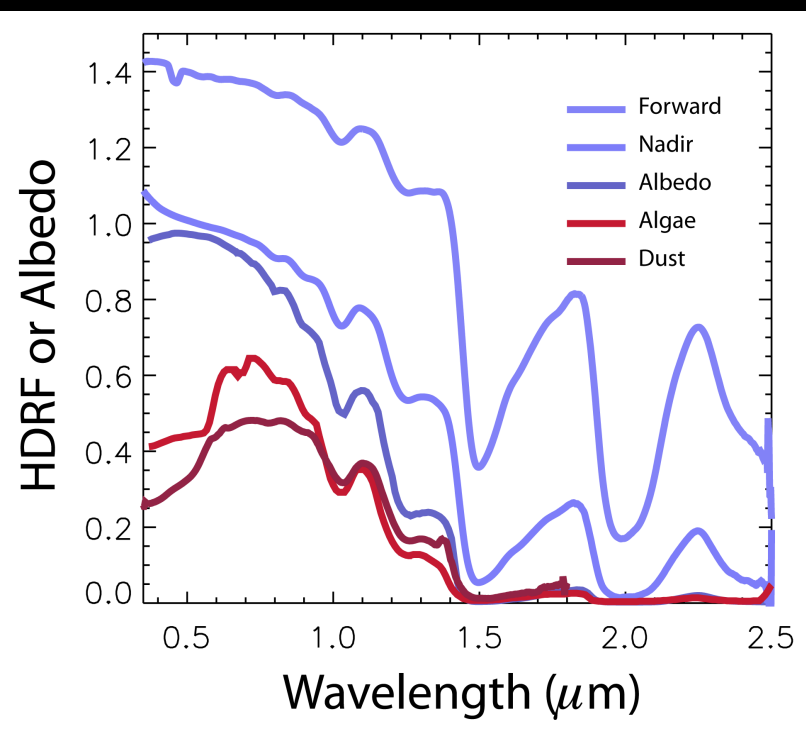
- Karl Rittger, Caltech postdoctoral fellow
- Cameron Goodale, JPL/Caltech
- Andrew Hart, JPL/Caltech
- Paul Ramirez, JPL/Caltech
- Felix Seidel, Caltech postdoctoral fellow
- Paul Zimdars, JPL/Caltech



Outline



- 1 Fractional Snow Covered Area – MODSCAG
- 2 Dust/BC Radiative Forcing in Snow – MODDRFS
- 3 Annual Minimum Snow and Ice – MODICE
- 4 8-day composites
- 5 NCA reports
- 6 AGU presentations





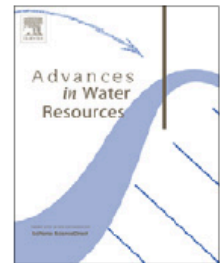
Advances in Water Resources xxx (2012) xxx–xxx



Contents lists available at [SciVerse ScienceDirect](#)

Advances in Water Resources

journal homepage: www.elsevier.com/locate/advwatres



Assessment of methods for mapping snow cover from MODIS

Karl Rittger^a, Thomas H. Painter^b, Jeff Dozier^{a,*}

^aBren School of Environmental Science & Management, University of California, Santa Barbara, CA 93106-5131, United States

^bJet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr, Pasadena, CA 91109, United States

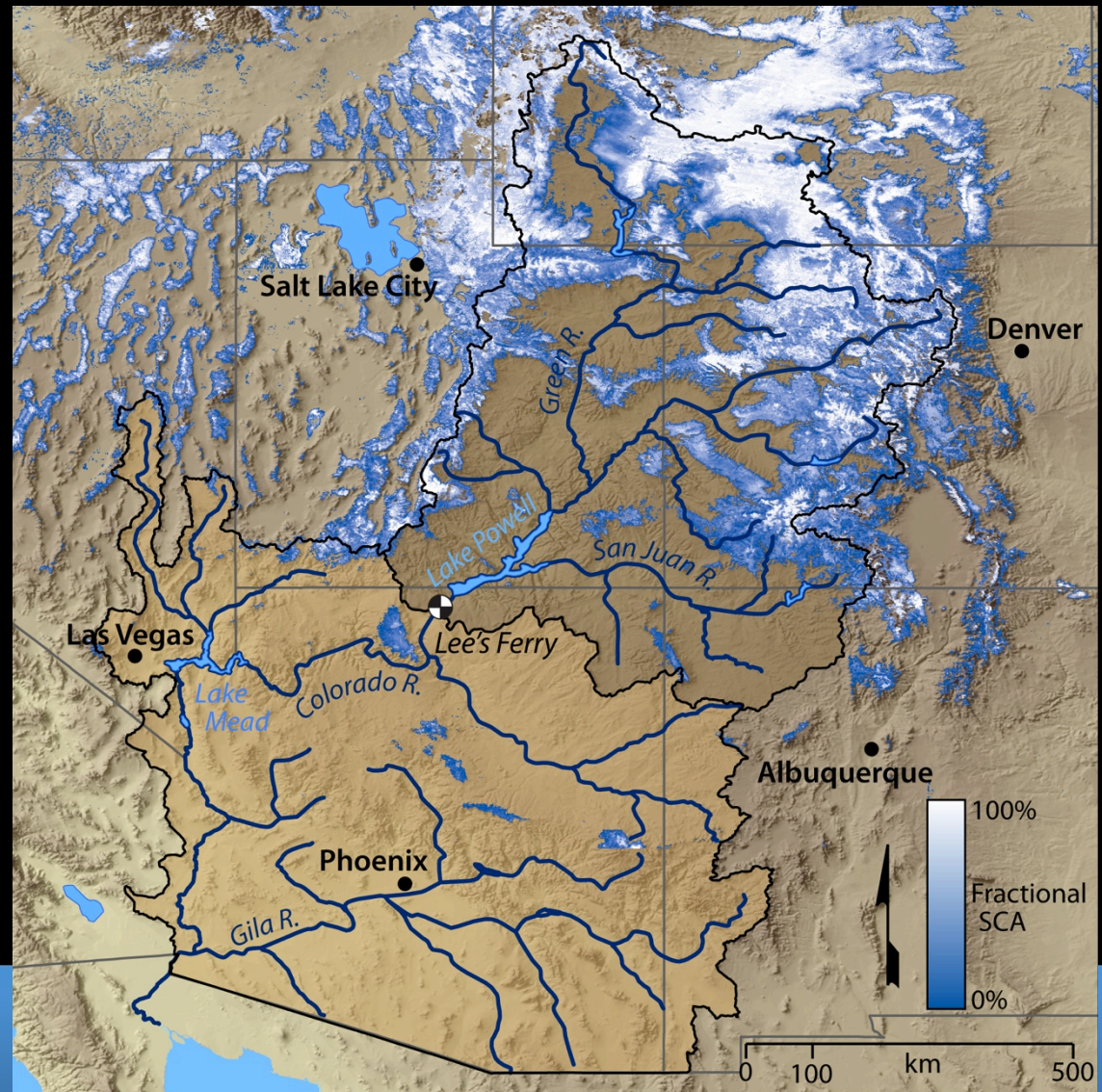


MODSCAG Snow Cover



MODSCAG processing

- Western US complete (2000-present)
- Near real time processing ongoing
- Alaska processing ongoing
- Many users of the data already, accessed through JPL Snow Data Server





Time-Space Continuity



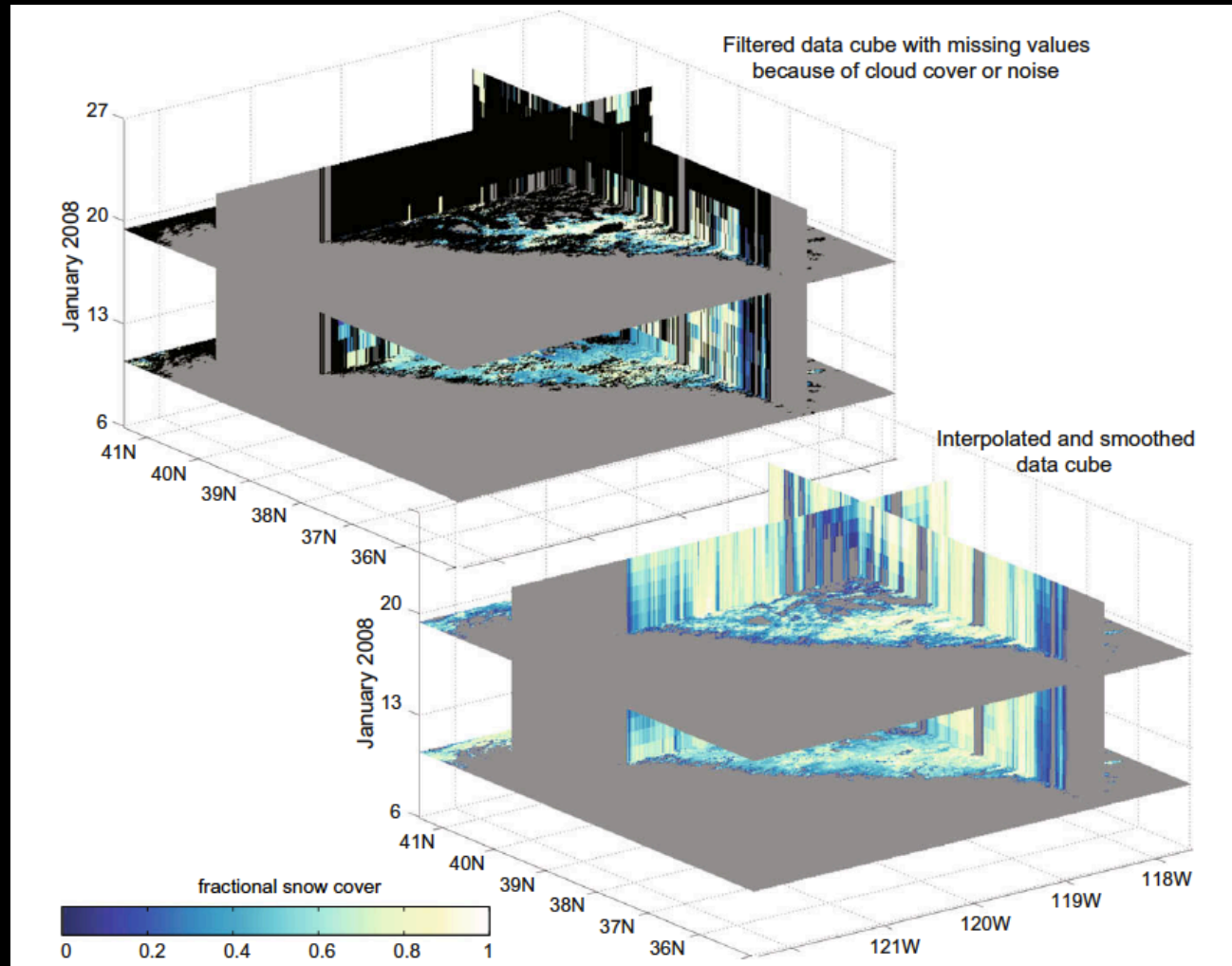
Value added products

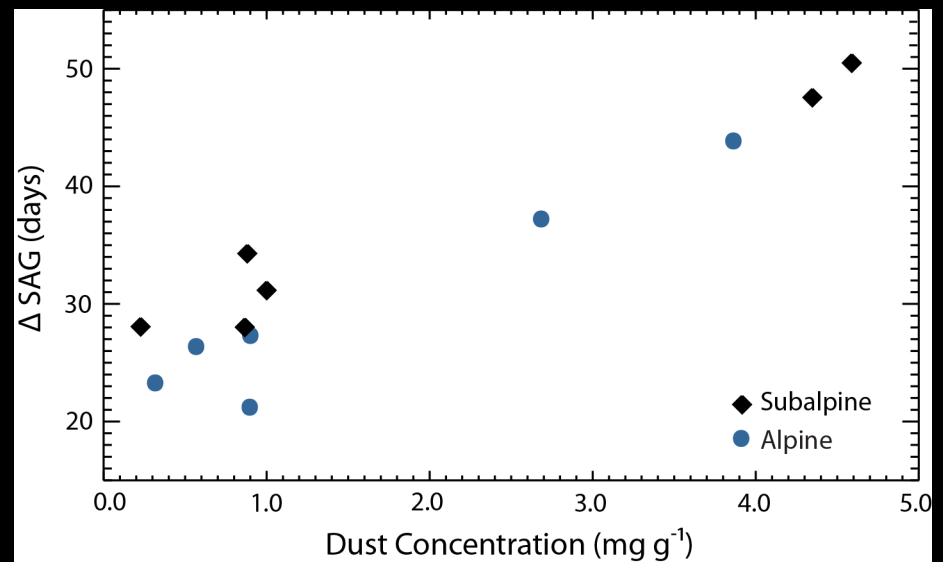
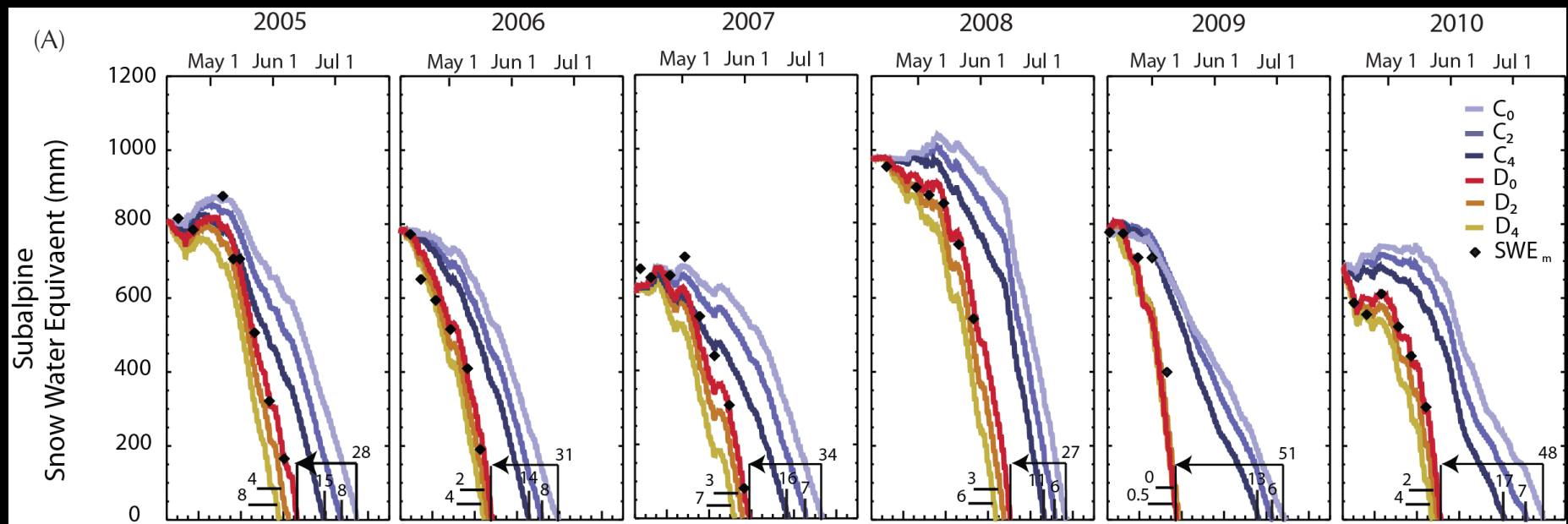
Time-space filtering of instantaneous MODSCAG retrievals to spatially and temporally continuous fields of fractional snow covered area and albedo.

Constrained by cloud cover, sensor geometry

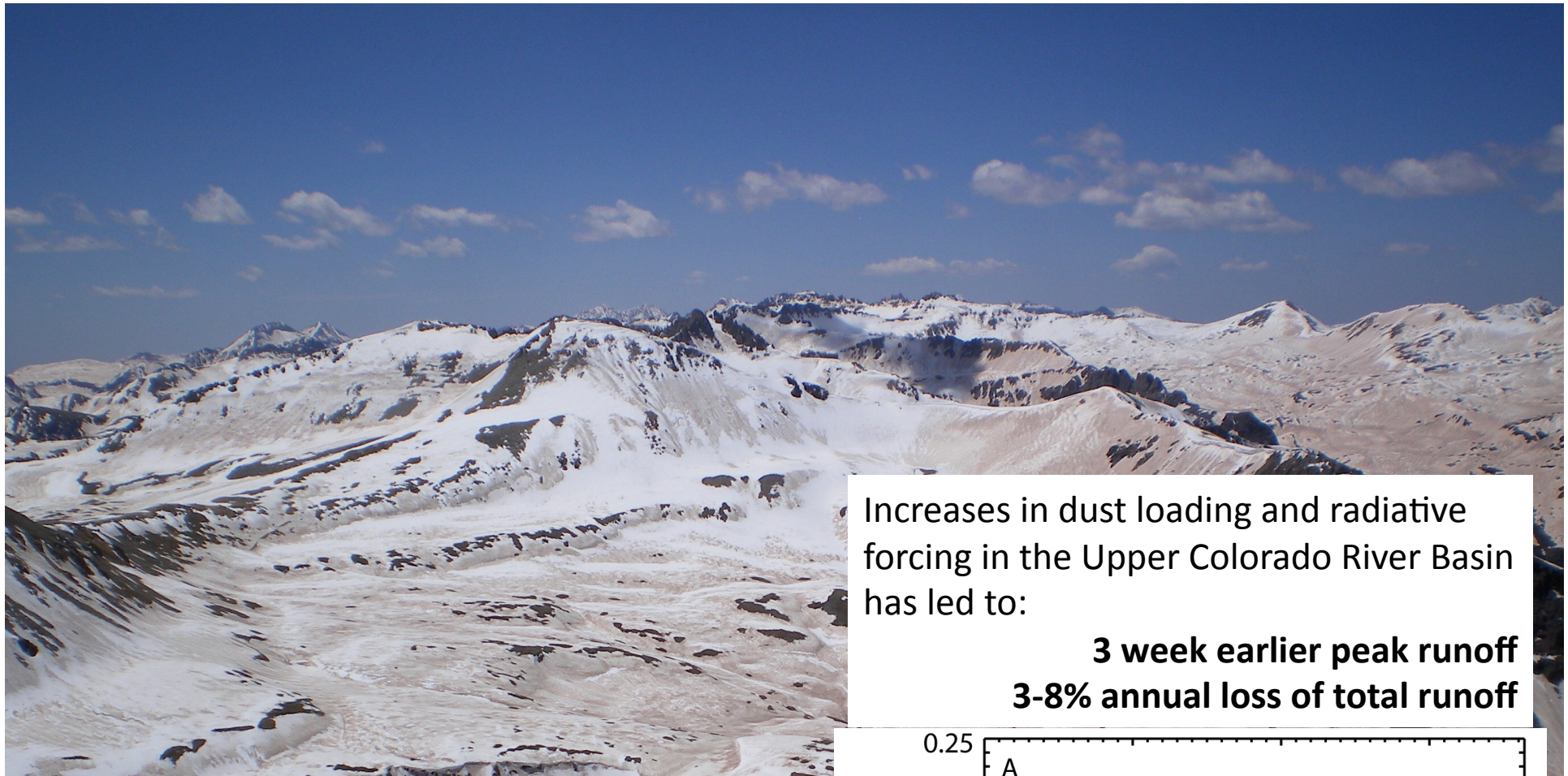
Available on Snow Data Server

Dozier et al 2008





Skiles et al 2012 WRR



Increases in dust loading and radiative forcing in the Upper Colorado River Basin has led to:

3 week earlier peak runoff
3-8% annual loss of total runoff

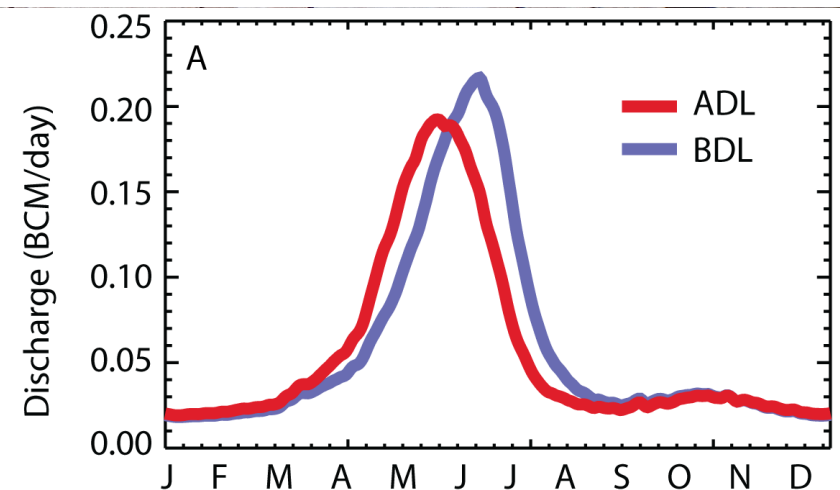
Response of Colorado River runoff to dust radiative forcing in snow

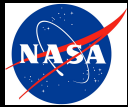
Thomas H. Painter^{a,b,1}, Jeffrey S. Deems^{c,d}, Jayne Belnap^e, Alan F. Hamlet^f, Christopher C. Landry^g

^aJet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109; ^bJoint Institute for Regional Earth System Science/University of California, Los Angeles, CA 90095; ^cNational Snow and Ice Data Center, Boulder, CO 80309; ^dNational Oceanic and Atmospheric Administration Western Water Assessment, Boulder, CO 80309; ^eUnited States Geological Survey, Southwest Biological Center, Flagstaff, AZ 86001; ^fUniversity of Washington, Department of Civil and Environmental Engineering, Seattle, WA 98195; and ^gCenter for Snow and Avalanche Studies, Silverton, CO 81433

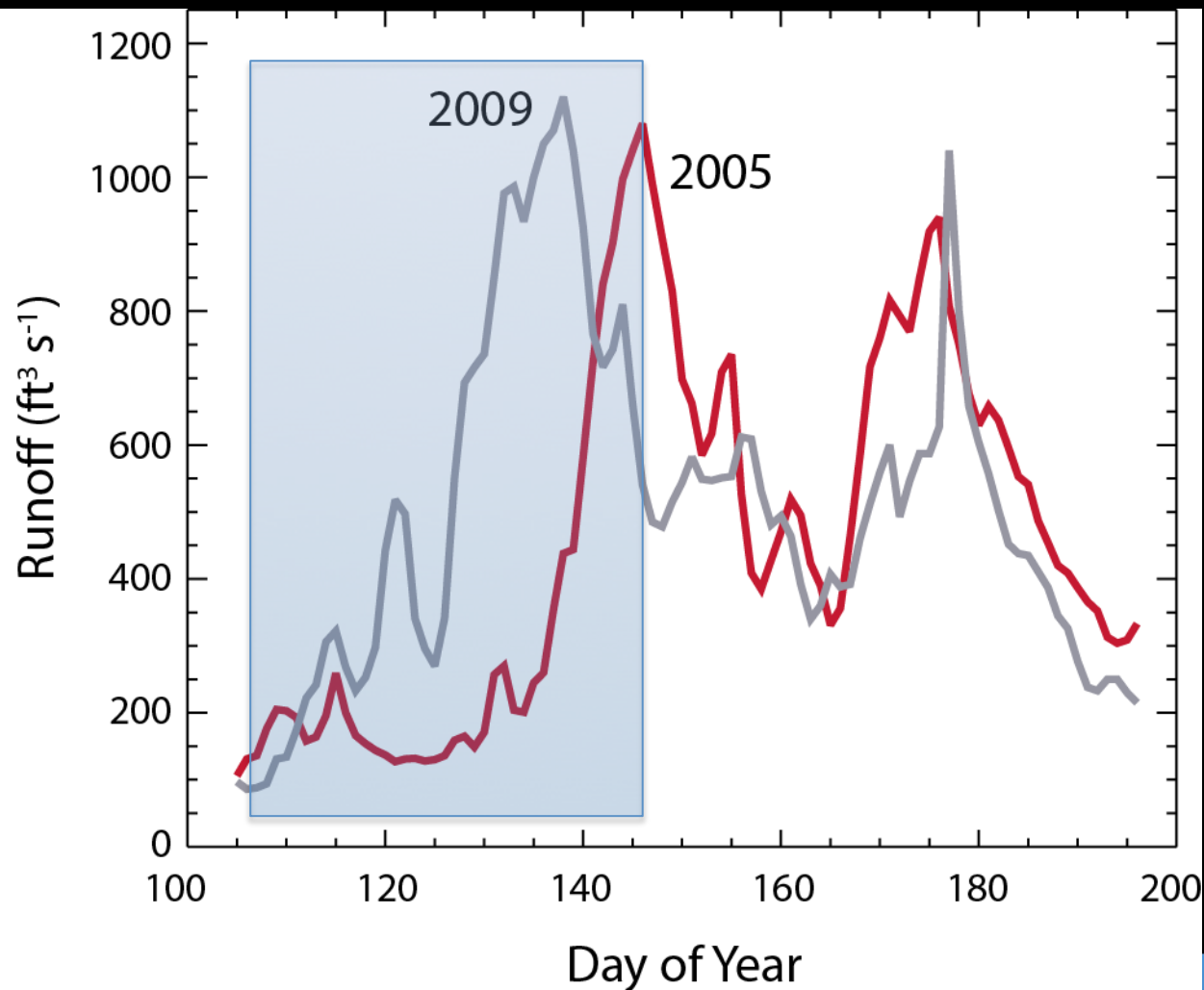
Edited by Peter H. Gleick, Pacific Institute for Studies in Development, Environment, and Security, Oakland, CA, and approved November 12, 2009

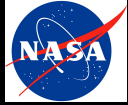
The waters of the Colorado River serve 27 million people in seven states and two countries but are overallocated by more than 10% through dust's direct absorption and accelerated snow metamorphism. P



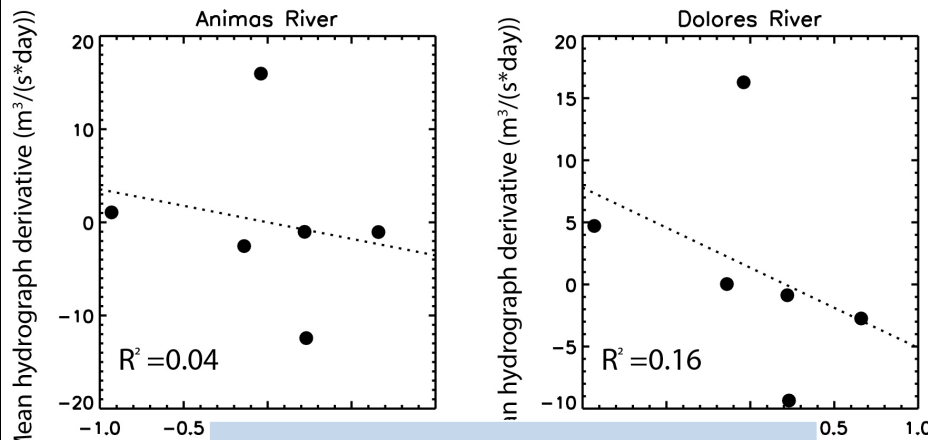


Controls on the interannual variability of the snowmelt runoff hydrograph?

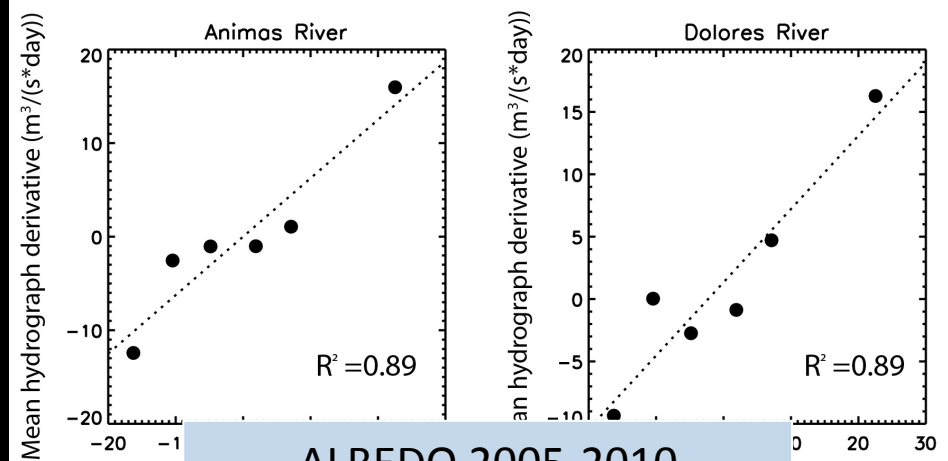
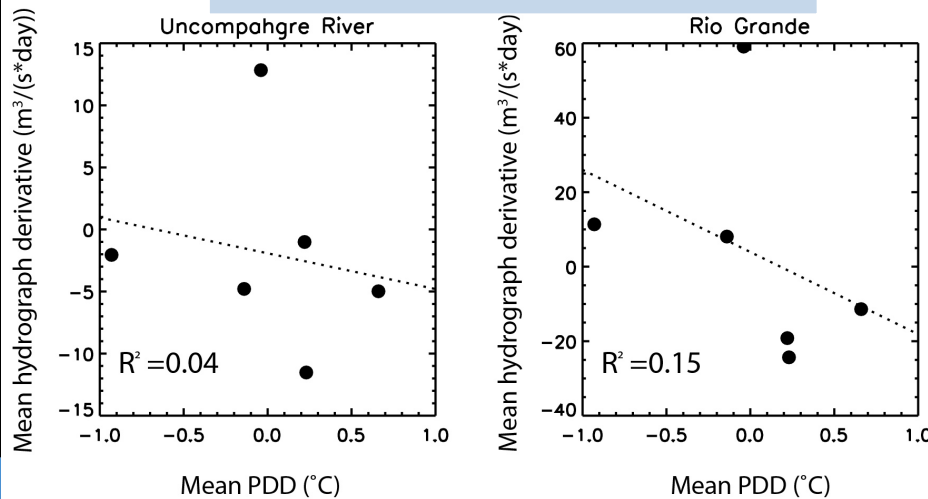




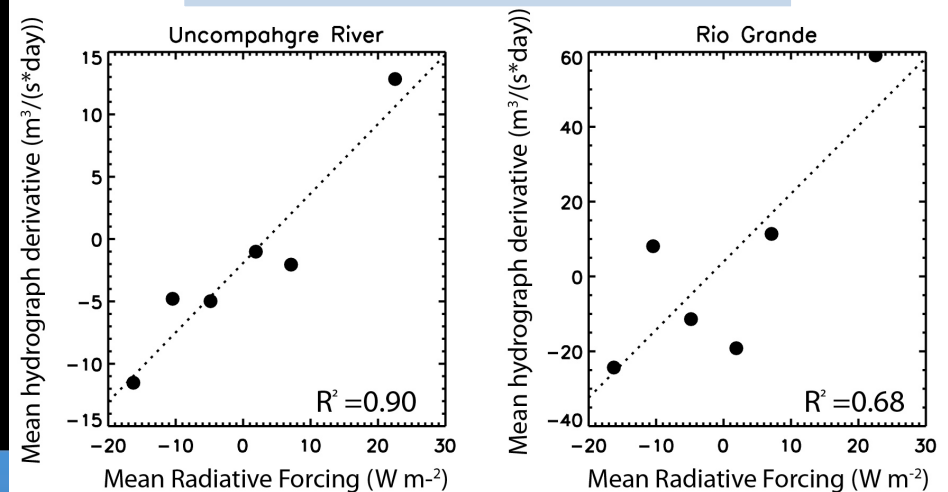
Steepness of rising limb



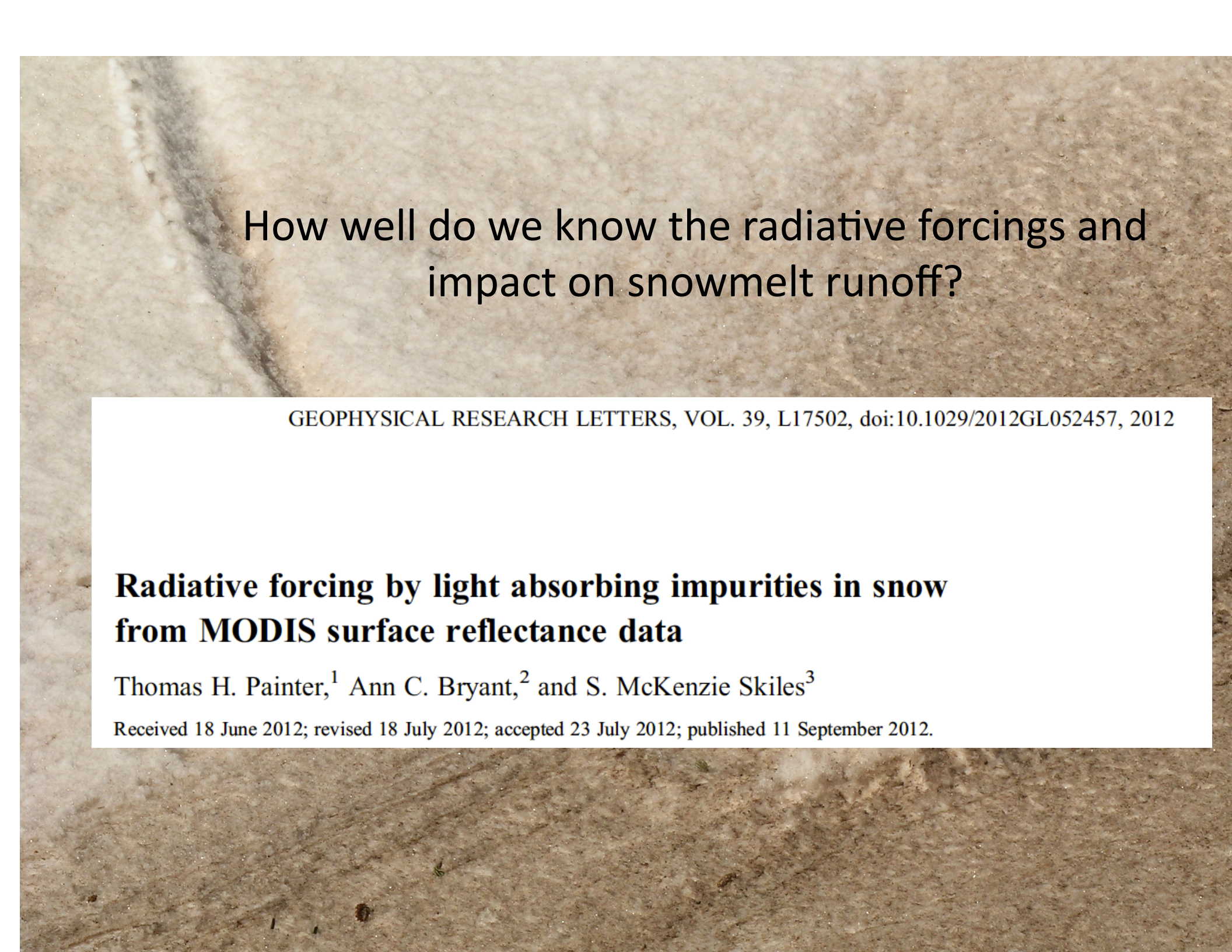
TEMPERATURE 2005-2010



ALBEDO 2005-2010



Painter et al (in preparation)



How well do we know the radiative forcings and
impact on snowmelt runoff?

GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L17502, doi:10.1029/2012GL052457, 2012

**Radiative forcing by light absorbing impurities in snow
from MODIS surface reflectance data**

Thomas H. Painter,¹ Ann C. Bryant,² and S. McKenzie Skiles³

Received 18 June 2012; revised 18 July 2012; accepted 23 July 2012; published 11 September 2012.



MODDRFS



MODIS Dust Radiative Forcing in Snow

Determine clean snow spectrum

$$NDGSI = \left(\frac{MODIS_2 - MODIS_5}{MODIS_2 + MODIS_5} \right)$$

With DEM, determine local illumination geometry

$$\cos\beta = \cos\theta_s \cos\theta_n + \sin\theta_s \sin\theta_n \cos\{\phi_s - \phi_n\}$$

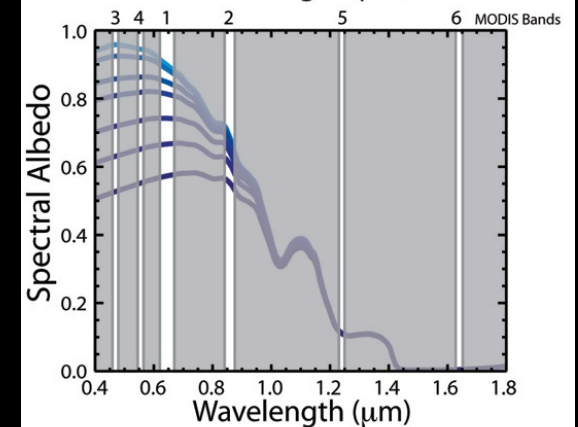
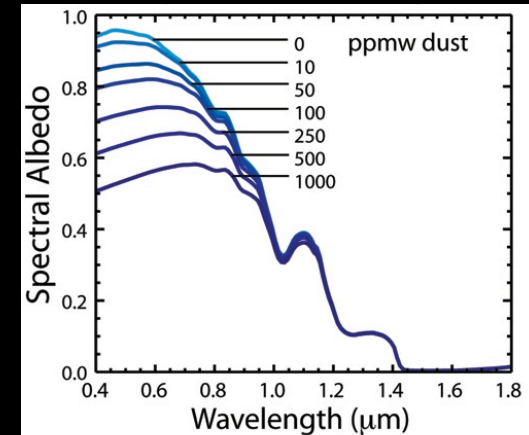
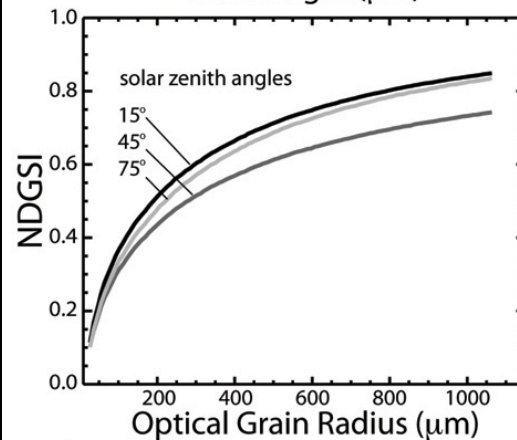
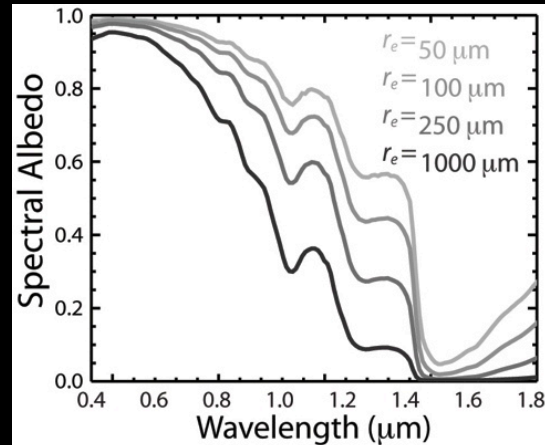
and local illumination

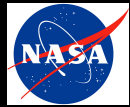
$$E_{corrected,\lambda} = (E_{direct,\lambda} \cos\beta) + E_{diffuse,\lambda}$$

and radiative forcing at 500 m scale

$$\alpha_{clean,\lambda} = c(\lambda; \theta_0; \theta_r, \phi_r; \zeta_{atm}) \cdot R(\lambda; \theta_0; \theta_r, \phi_r; \zeta_{atm})$$

$$F = \sum_{\lambda=0.35\mu m}^{\lambda=0.876\mu m} E_{corrected,\lambda} (\alpha_{clean,\lambda} - \alpha_{MODIS,\lambda}) \Delta\lambda$$



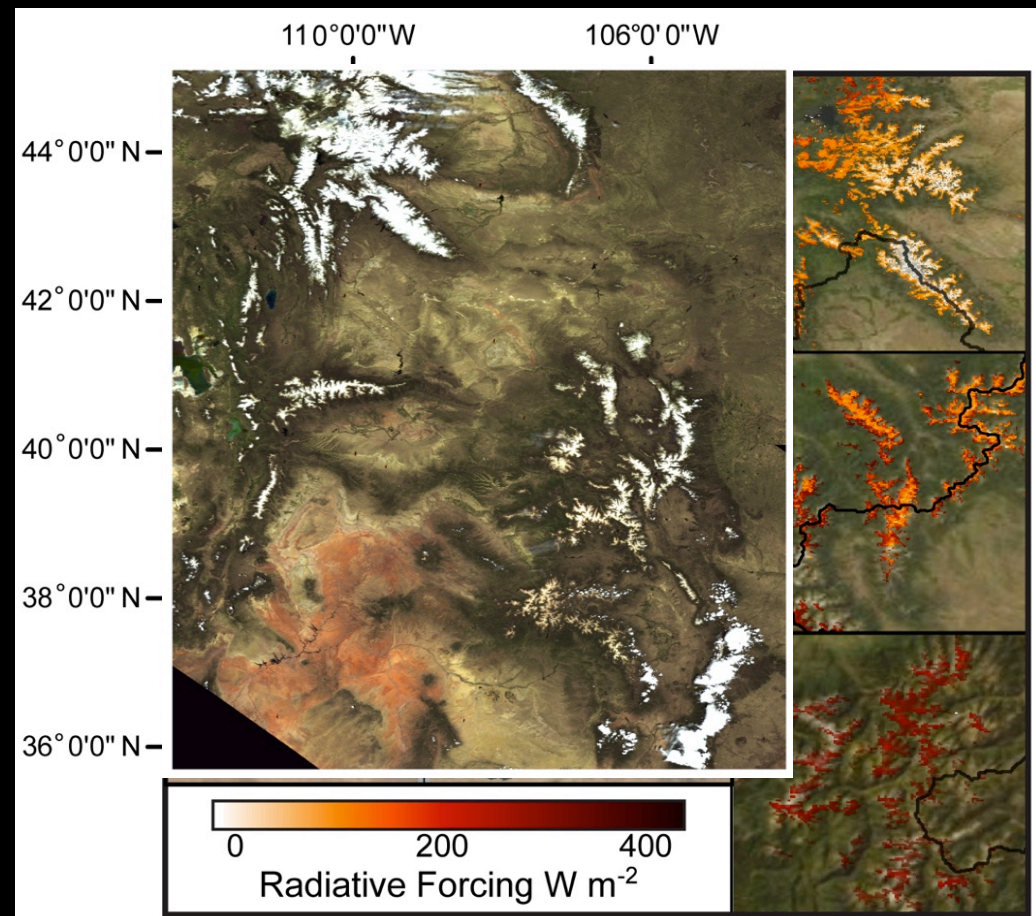


MODDRFS Radiative Forcing



MODDRFS processing

- Western US complete (2000-present)
- Near real time processing ongoing
- Alaska processing ongoing
- Many users of the data already, accessed through JPL Snow Data Server

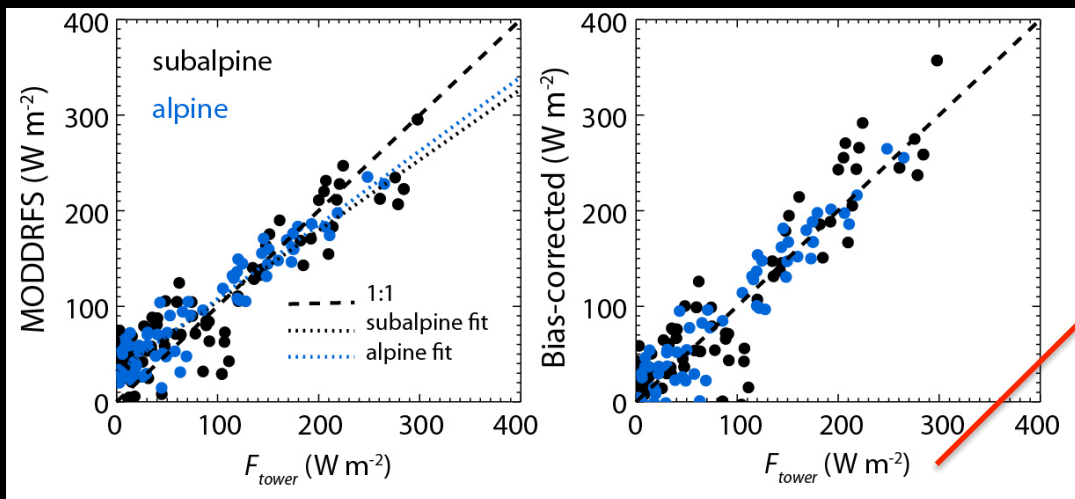


MODDRFS Dust Radiative Forcing

Colorado River Basin, Western US



MODDRFS



RMSE $32 W m^{-2}$; MAE $25 W m^{-2}$

Painter et al 2007; Painter et al 2012a



Senator Beck Basin Study Area, SW Colorado



MODIS Permanent Ice (MODICE)



GEOPHYSICAL RESEARCH LETTERS, VOL. 39, LXXXXX, doi:10.1029/2012GL053340, 2012

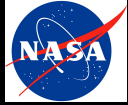
1 Automated mapping of Earth's annual minimum exposed snow 2 and ice with MODIS

3 Thomas H. Painter,¹ Mary J. Brodzik,² Adina Racoviteanu,³ and Richard Armstrong²

4 Received 31 July 2012; revised 12 September 2012; accepted 19 September 2012; published XX Month 2012.

The Global Land Ice Measurements from Space (GLIMS) project has compiled digital glacier outlines and related metadata for the majority of the world's glaciers but inconsistency among product algorithms and time periods represented precludes the production of a consistently derived global dataset.

Currently a fundamental missing component of the world cryosphere inventory is a single systematically derived base map of the world's glaciers and annual minimum snow cover, at any scale.



MODICE Annual Minimum Exposed Snow and Ice

Annually resolved across the full EOS record.

Time series of MODSCAG retrievals to shrink-wrap annual minimum exposed snow and ice.

Constrained by cloud cover and sensor zenith, we chip away at snow/ice with non-snow pixels.

Cloud



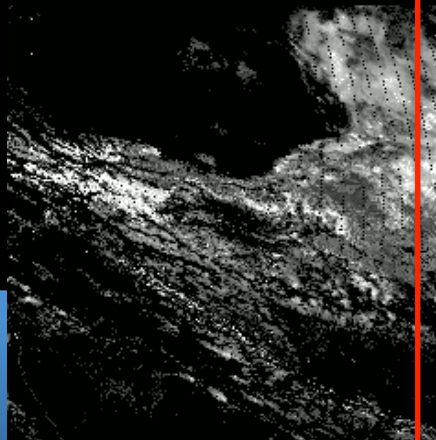
Zenith

"Other" (ice) data w/Adequate

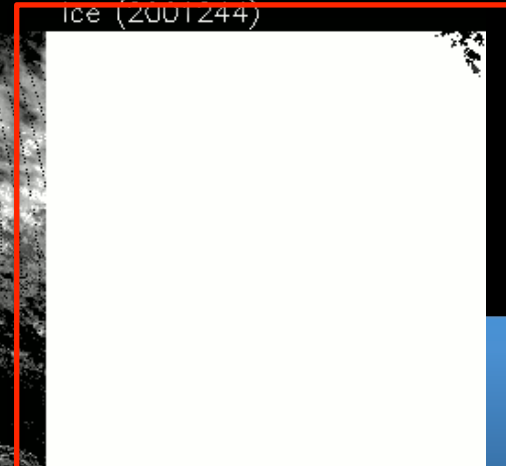


Mask

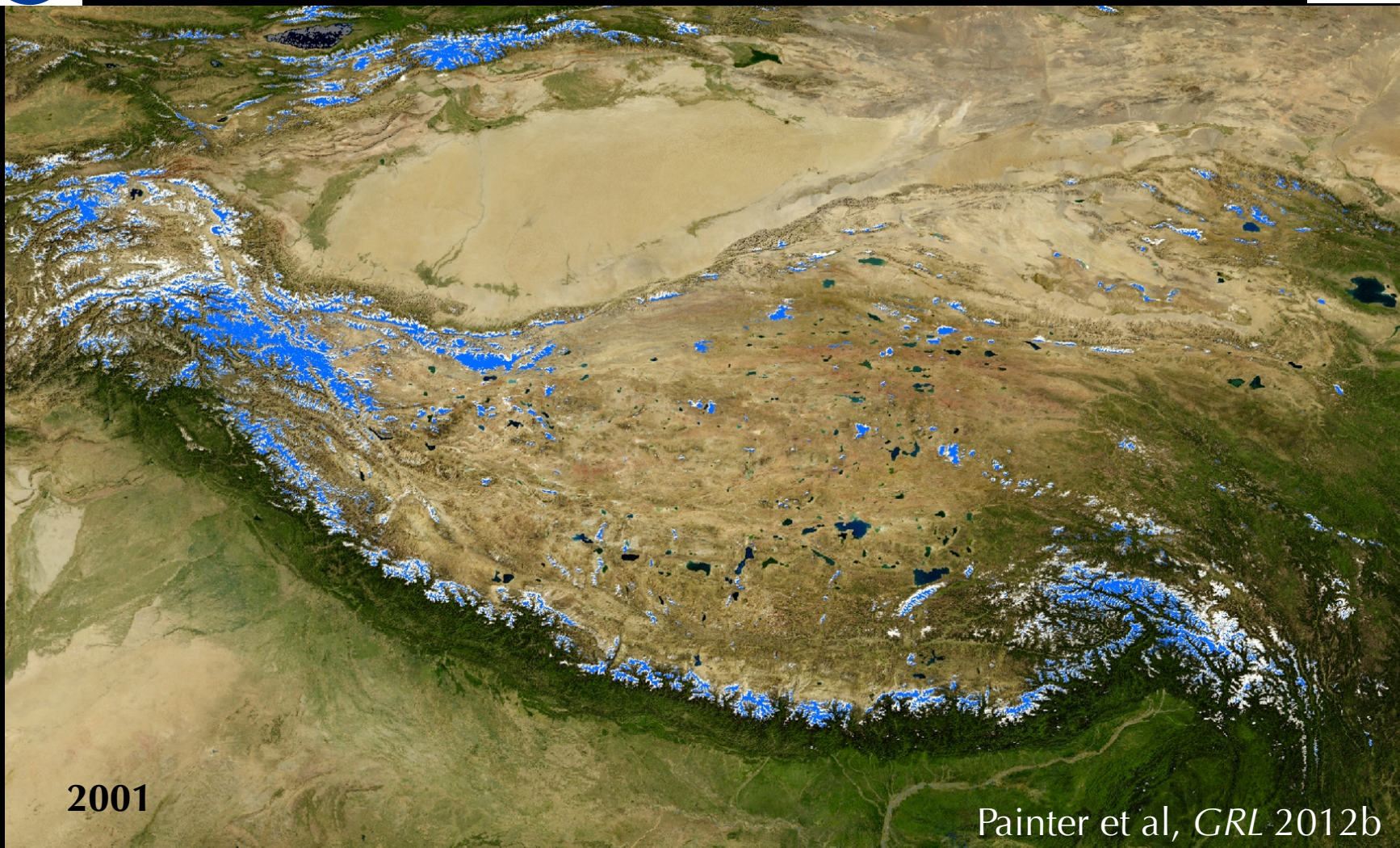
Snow



Ice (2001244)



Karakoram/Himalaya/Tibetan Plateau

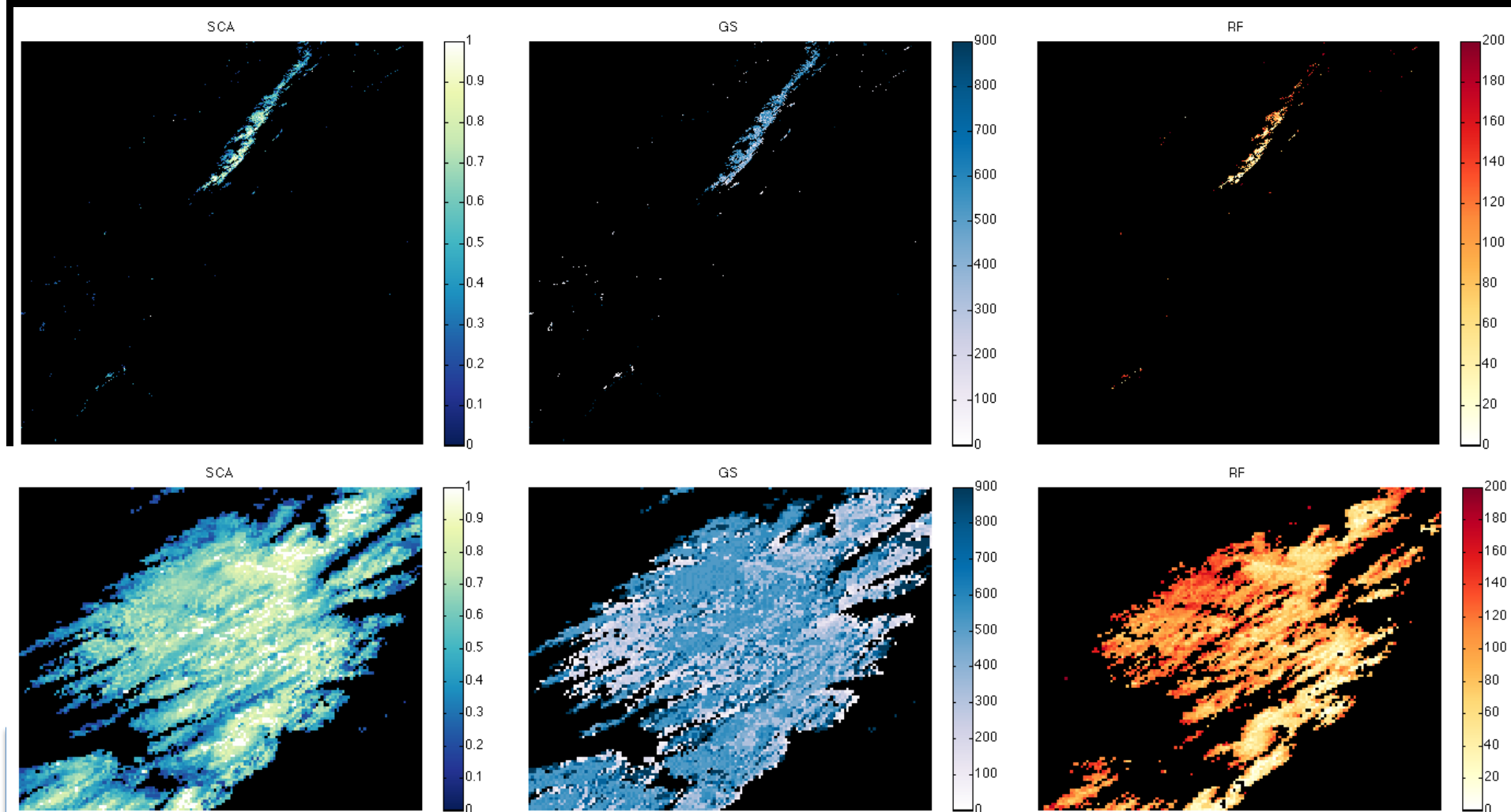


2001

Painter et al, GRL 2012b



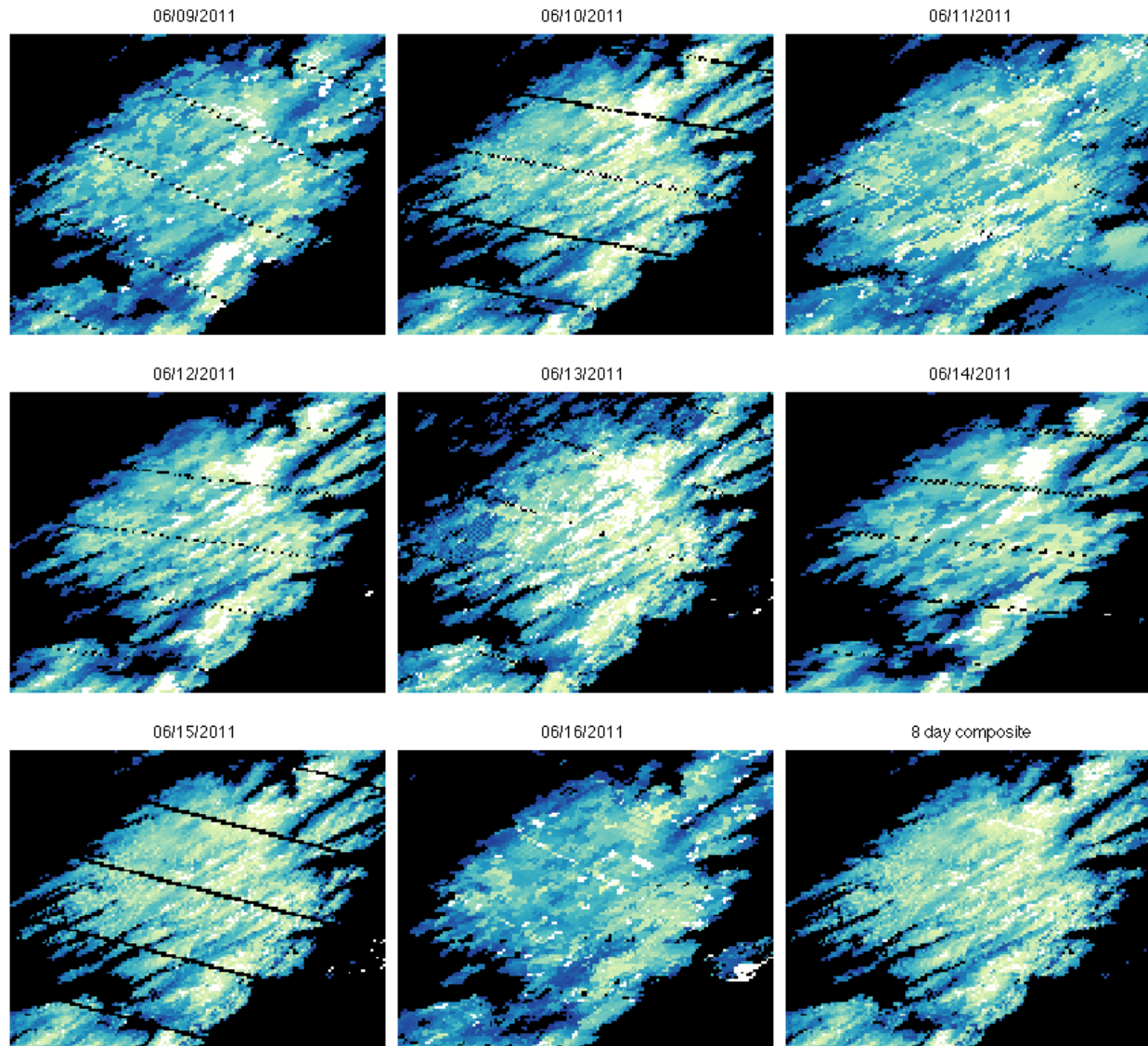
All final products, June 09, 2011 h08v05 & Tuolumne





Snow Cover, June 09, 2011

8 days of input & final product

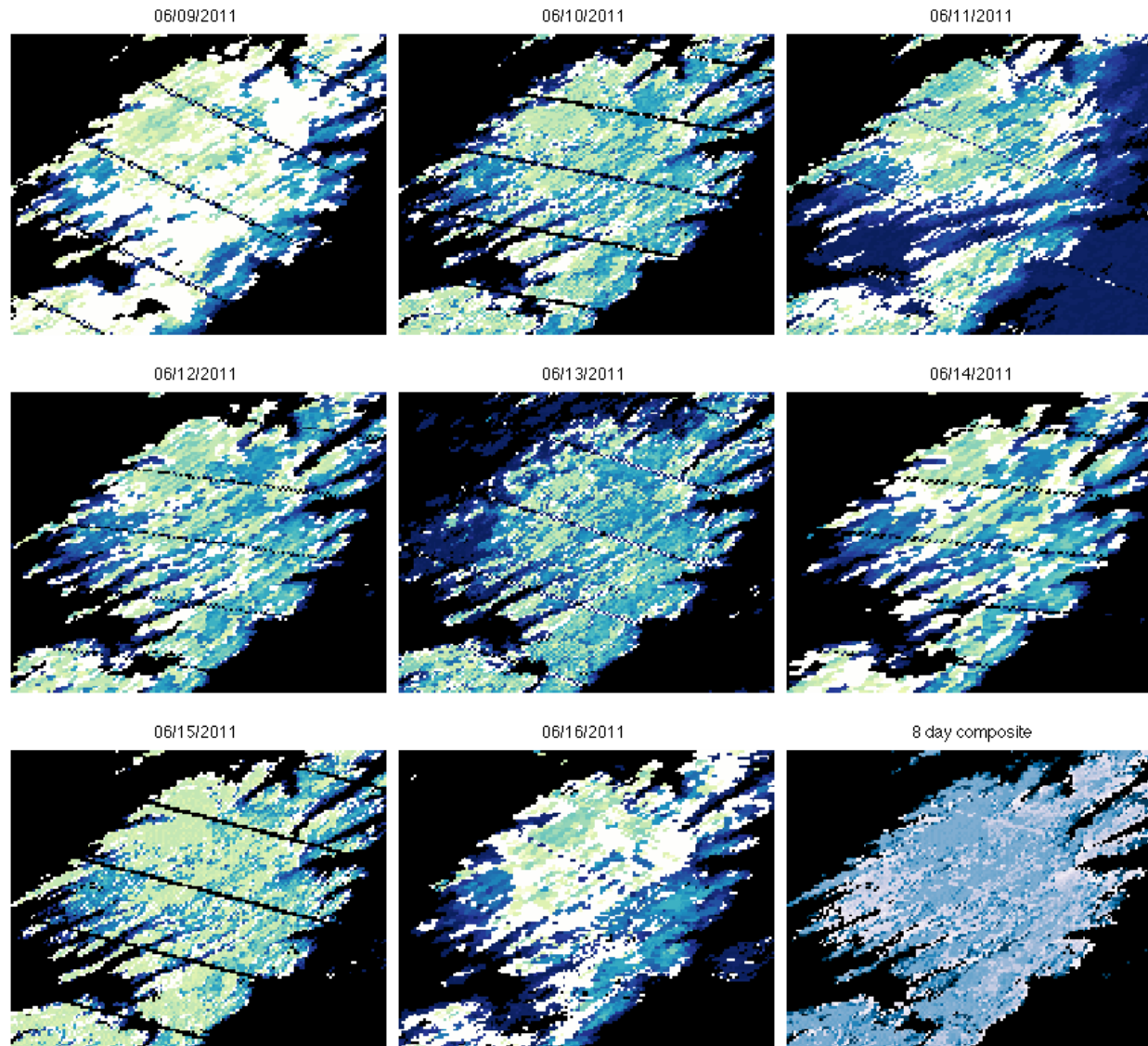


product



Grain Size, June 09, 2011

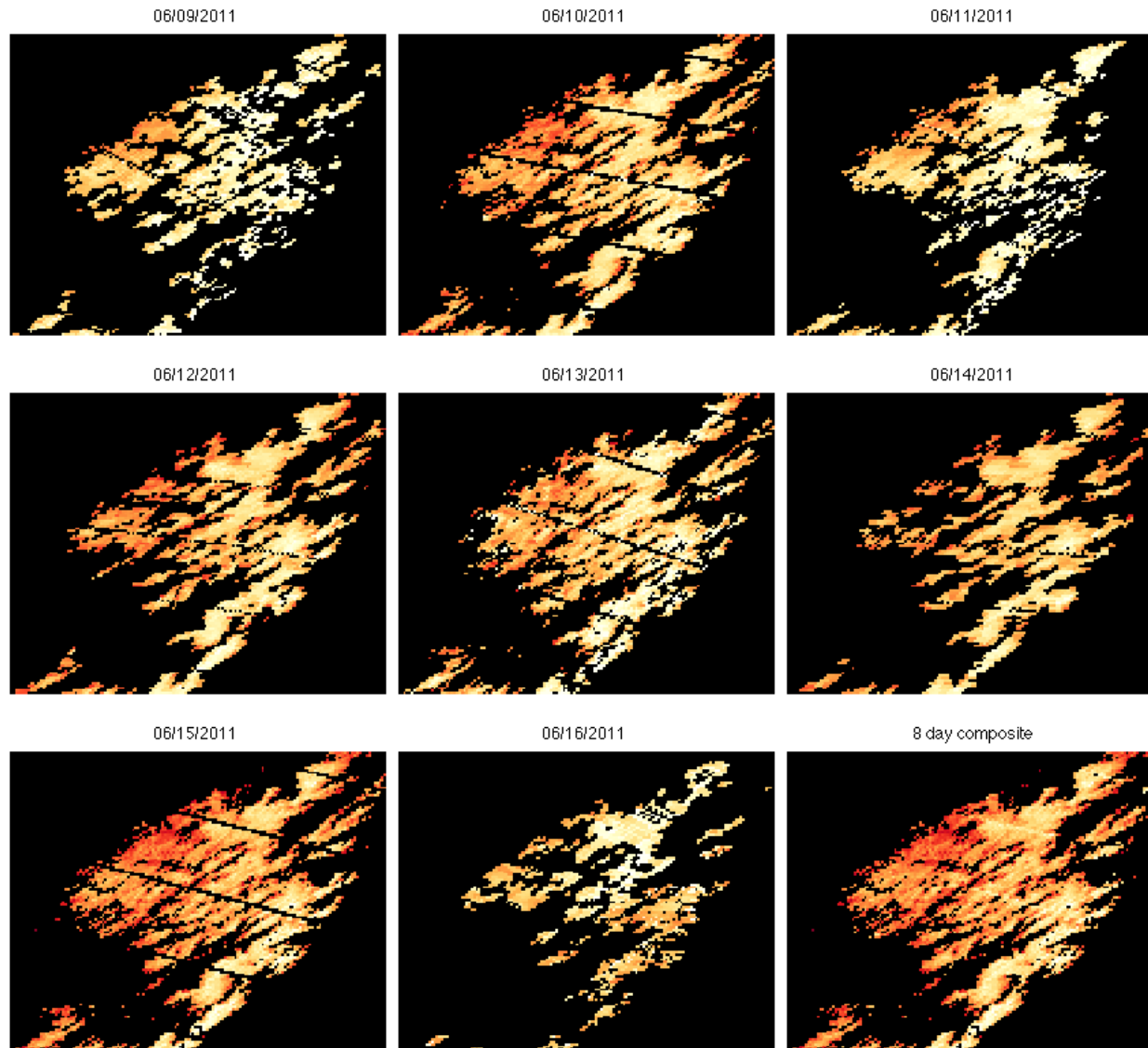
8 days of input & final product



product

Radiative Forcing, June 09, 2011

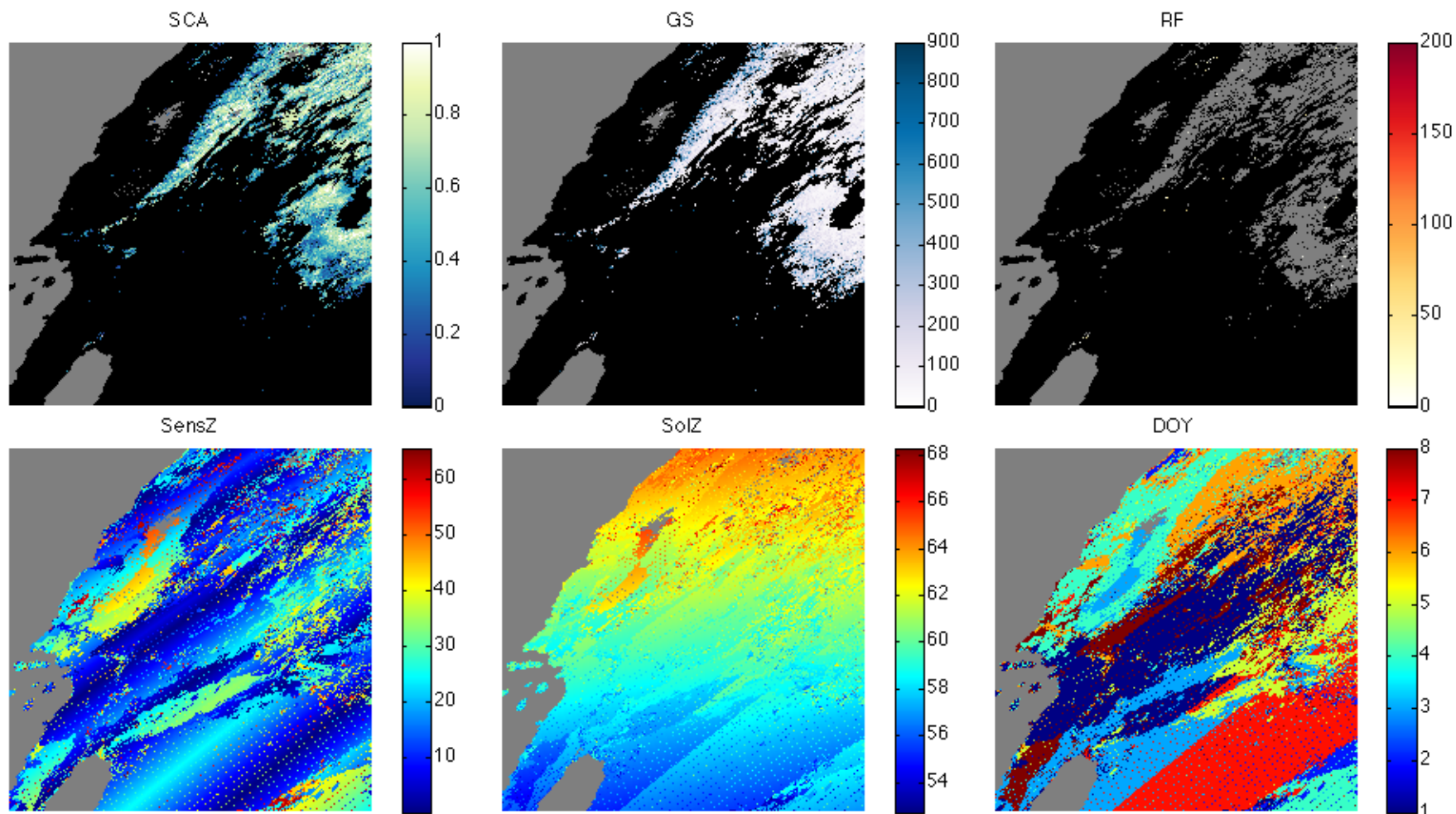
8 days of input & final product



product



H08v05 2011001





JPL Snow Data Server



MODIS historical processing

MODIS Near Real Time (NRT) processing

The screenshot shows the 'Snow Data System Browser' interface. At the top, there's a NASA logo and the Jet Propulsion Laboratory name. Below that, a navigation bar includes 'Home', 'Data', 'Publications', 'Media', 'People', and 'Links'. The 'Data' tab is selected. The main content area has a search bar and a table of 'Surface Reflectance Products'. The table lists two products: MOD09GA and MOD09GANRT. MOD09GA is described as 'The MODIS Surface Reflectance products provide an estimate of the surface spectral reflectance as it would be measured at ground level in the absence of atmospheric scattering or absorption. Low-level data are corrected for atmospheric gases and aerosols, yielding a level-2 basis for several higher-order gridded level-2 (L2G) and level-3 products. MOD09GA provides Bands 1-7 in a daily gridded L2G product in the Sinusoidal projection, including 500-meter reflectance values and 1-kilometer observation and geolocation statistics. 500-m Science Data Sets provided for this product include reflectance for Bands 1-7, a quality rating, observation coverage, observation number, and 250-m scan information. 1-kilometer Science Data Sets provided include number of observations, quality state, sensor angles, solar angles, geolocation flags, and orbit pointers. Version-5 MODIS/Terra Surface Reflectance products are Validated Stage 2, meaning that accuracy has been assessed over a widely distributed set of locations and time periods via several ground-truth and validation efforts. Although there may be later improved versions, these data are ready for use in scientific publications.' MOD09GANRT is described as 'This subset of MODIS Surface Reflectance files have been sourced from the LANCE Near Real Time data repository. They have not been through the same quality control process that the traditional MOD09GA products do.'

Name	Description	Id
MOD09GA	The MODIS Surface Reflectance products provide an estimate of the surface spectral reflectance as it would be measured at ground level in the absence of atmospheric scattering or absorption. Low-level data are corrected for atmospheric gases and aerosols, yielding a level-2 basis for several higher-order gridded level-2 (L2G) and level-3 products. MOD09GA provides Bands 1-7 in a daily gridded L2G product in the Sinusoidal projection, including 500-meter reflectance values and 1-kilometer observation and geolocation statistics. 500-m Science Data Sets provided for this product include reflectance for Bands 1-7, a quality rating, observation coverage, observation number, and 250-m scan information. 1-kilometer Science Data Sets provided include number of observations, quality state, sensor angles, solar angles, geolocation flags, and orbit pointers. Version-5 MODIS/Terra Surface Reflectance products are Validated Stage 2, meaning that accuracy has been assessed over a widely distributed set of locations and time periods via several ground-truth and validation efforts. Although there may be later improved versions, these data are ready for use in scientific publications.	urn:snow:MOD09GA
MOD09GANRT	This subset of MODIS Surface Reflectance files have been sourced from the LANCE Near Real Time data repository. They have not been through the same quality control process that the traditional MOD09GA products do.	urn:snow:MOD09GANRT

Showing 1 to 2 of 2 entries

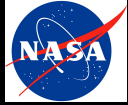
Snow Products

Name	Description	Id
MODDRFS	MODDRFS is short for MODIS Dust Radiative Forcing in Snow. This Product Type is the final output from the Snow Data Management System.	urn:snow:MODDRFS
MODSCAG	MODSCAG is short for MODIS Snow Covered Area and Grain size. This Product Type is the final output from the Snow Data Management System after using the MODSCAG IDL Routines	urn:snow:MODSCAG

Powered by SnowDS and Apache OODT — Tiles: © ESR

The screenshot shows the 'Snow Data System Browser' interface for NRT processing. It features a date selector set to 'Wed Nov 07 2012'. Below the date, there are checkboxes for 'Snow Cover', 'Grain Size', 'Dust Forcing', 'Clouds', 'Rocks', 'Vegetation', and 'Shade'. The 'Snow Cover' checkbox is checked. There are also buttons for 'Full Screen' and 'Regions: United States High Asia'. The main content area displays a satellite image of a snowy mountain range. The image is overlaid with a grid and a color scale. The bottom of the image has a footer that reads 'Powered by SnowDS and Apache OODT — Tiles: © ESR'.

<http://snow.jpl.nasa.gov/>




JPL Snow Data Server



Jet Propulsion Laboratory
California Institute of Technology

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SNOW DATA SYSTEM

Welcome to the Snow Data System

About This Site...

Welcome to the JPL Snow Data System. The Snow Data System serves cutting edge snow-related satellite and airborne remote sensing data, energy balance data for the Western US, and snow services targeting the snow, ice, climate, and water management communities.

For information about the project or comments, please contact:

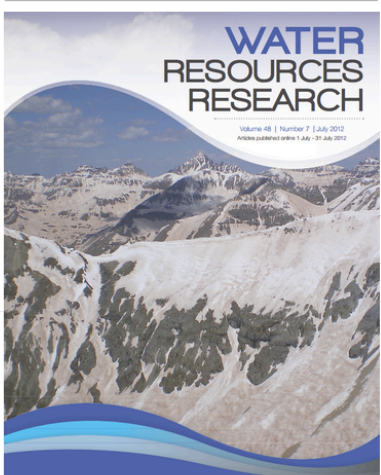
Thomas Painter (thomas.painter@jpl.nasa.gov)
Chris Mattmann (chris.a.mattmann@nasa.gov)

Latest News

24.Sept.2012
[Avalanche on Manasku, Nepal](#)

15.Feb.2012
<http://www.nytimes.com/2012/02/16/science/earth/pushes-to-cut-emissions-that-speed-climate-change.html?ref=science>

Latest Images



WATER RESOURCES RESEARCH
Volume 48 | Number 7 | July 2012
Articles published online 1 July 2012

AGU PUBLISHED BY THE AMERICAN GEOPHYSICAL UNION

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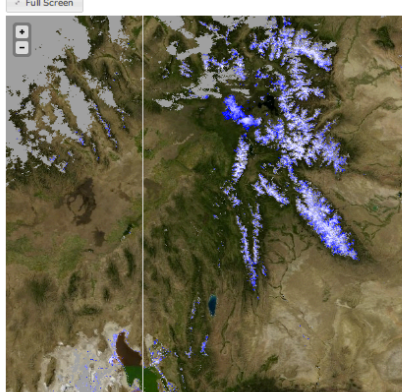
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Date: Wed Nov 07 2012 2012-11-07

☒ Snow Cover ☐ Grain Size ☐ Dust Forcing ☐ Clouds ☐ Rocks ☐ Vegetation ☐ Shade

☐ Full Screen



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Data Western Energy Balance Of Snow

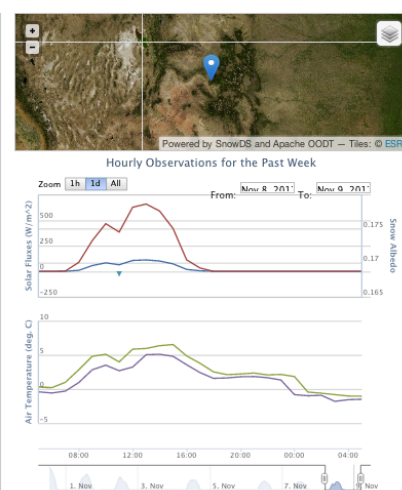
Grand Mesa Study Plot

39°3'2.956" N, -108°3'41.112" W

Grand Mesa Study Plot (GMSP) is located in an opening in a pine forest on the northern rim of Grand Mesa, at 3239m. Grand Mesa, located in western Colorado just east of Grand Junction, is the largest flat-topped mountain in the world with elevation ranging between 3000m and 3550m.

GMSP was established by the Snow Optics Laboratory (JPL) with funding from the US Geological Survey in October 2009 to augment measurements being made in Senator Beck Basin Study Area (SBBBSA) in the San Juan Mountains of southwestern CO, about 150 km south of GMSP. This site was chosen to capture spatial variability in dust loading and radiative forcing impacts. The high elevation of the mesa means that snowcover is established and maintained through out the winter and lasts longer than snow in the surrounding low lying terrain. All water from the mesa drains to the Colorado River through various tributaries.

The instrumentation array at GMSP is designed to measure snow energy balance similar to, but somewhat less extensive than, the two sites at SBBBSA. This site is equipped to measure incoming and outgoing solar (shortwave) and thermal (longwave) radiation fluxes, snowpack depth, wind speed and direction, air temperature, and humidity.



Hourly Observations for the Past Week

Zoom 1h 1d All From: Nov 8, 2011 To: Nov 9, 2011

Solar Fluxes (W/m²)

Air Temperature (deg. C)

Snow Albedo

<http://snow.jpl.nasa.gov/>



NCA report



Assessment of Climate Change in the Southwest United States: A Technical Report Prepared for the U.S. National Climate Assessment

We have submitted our edits and author approvals for Chapter 4: *The Weather and Climate of the Southwest United States*

It is to be in press very soon.



AGU presentations



- Monday, 8AM-10AM, posters: IN11D-1475. Building a Snow Data Management System using Open Source Software (and IDL)
Cameron E. Goodale; Chris A. Mattmann; Paul Ramirez; Andrew F. Hart; Thomas Painter; Paul A. Zimdars; Ann Bryant; Mary Jo Brodzik; McKenzie Skiles; Felix C. Seidel; Karl E. Rittger
- Tuesday, 8AM-10AM, posters: C21C-0612. Validation and application of MODIS-derived clean snow albedo and dust radiative forcing
Karl E. Rittger; Ann C. Bryant; Felix C. Seidel; Edward H. Bair; McKenzie Skiles; Cameron E. Goodale; Paul Ramirez; Chris A. Mattmann; Jeff Dozier; Thomas Painter
- Wednesday, 11:00AM, Moscone West 3007, C32B-06. Spatial variability and hydrologic response to dust radiative forcing of snow in the Upper Colorado River Basin (Invited)
Ann C. Bryant; Thomas Painter
- Friday, 1:40-4:00PM, posters: C53C-0865. Radiative forcing by light absorbing impurities in snow in the Upper Colorado River Basin using MODIS surface reflectance data (Invited)
Ann C. Bryant; Thomas Painter; McKenzie Skiles
- Friday, 5:15-5:30PM (REALLY!?!?!), 104 Moscone South: IN54B-06. High fidelity remote sensing of snow properties from MODIS and the Airborne Snow Observatory: Snowflakes to Terabytes (Invited)
Thomas Painter; Chris A. Mattmann; Mary Jo Brodzik; Ann C. Bryant; Cameron E. Goodale; Andrew F. Hart; Paul Ramirez; Karl E. Rittger; Felix C. Seidel; Paul A. Zimdars